1   SPECIFICATION

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3   CONFIGURABLE CONNECTORIZED I/O SYSTEM

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5   This application claims priority from U.S. Provisional Application Serial Number

6   60/269,129 filed February 14, 2001.

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8   BACKGROUND OF THE INVENTION

9   1.   FIELD OF THE INVENTION

10   **[0001]**   The present invention relates generally to cabling and cabling systems,

11   and more particularly to a universal cabling system wherein the requirement for specific wire

12   interconnections between first and second devices is accomplished through use of a

13   programmable I/O module for making connection to the first device, and directing connections

14   from the first device to selected wires of a cable for connection to the second device.

15   2.   DESCRIPTION OF THE PRIOR ART

16   **[0002]**   Complex electrical/electronic systems often require custom cable

17   configurations. Cables are usually special configurations for a particular application. Even in

18   relatively simple systems such as home audio and small computer systems, a number of different

19   cables are typically required. In larger applications, such as industrial control systems, the

20   number of custom cable designs is extensive. In industrial control systems such as those that run

21   automotive plants, etc., interaction is required between control apparatus and sensors and

22   actuators. The apparatus providing the corresponding connections will be referred to as input

23   and output systems. Through the output system, the control system can turn on lights, pumps,

24   valves and other devices. Similarly, through the input system, the control system can sense the

25   state of a pushbutton, whether a switch is on or off, or whether a tank is full or how fast a shaft is

26   turning.

27   **[0003]**   In prior art control systems, such as a Programmable Logic Controller

28   (PLC), the user of the control system electrically connects the sensors and actuators to the

29   input/output systems using individual wire connections or via connectorized wire harnesses. A

30   common method of connecting sensors and actuators to industrial control systems is through the

31   use of individual wire connections via *terminal blocks*. Terminal blocks usually employ a

32   screw-driven clamp. An electrical wire's insulation is removed from the end, and then the bare

33   wire is slid under the screw-driven clamp. The screw is then tightened to secure the wire under

34   the clamp and effect an electrical connection between the wire and the terminal block.

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1   Increasingly, various spring clamps are used to hold the wire, but these are essentially the same

2   as screw-driven clamps. Fig. 1 shows how individual wires 10 are connected to the input and

3   output Modules 12, 14 of a PLC 16 through terminal blocks 18 to three devices, a light bulb 20, a

4   switch 22 and a proximity switch 24. A proximity switch is a common type of switch that can

5   detect the presence (typically) of metal, and gives an indication by interrupting or passing

6   electrical current.

7   **[0004]**   A disadvantage of the method illustrated in Fig. 1 is that the

8   terminals 26, 28 on the input or output modules of the PLC 16 are not necessarily conveniently

9   arranged for facilitating easy connection of a load, such as a light bulb or switch. As a result, a

10   great deal of custom, hand-wiring must be performed in order to effect the interconnections. In

11   addition the electricity, from a supply 30 to power certain actuators and sensors such as the light

12   bulb or proximity sensor, must be provided on the terminal blocks 18 in order to make

13   connections to the light bulb or switch. In general, the prior art output Modules 12 and 14 do not

14   supply power to the load, they only switch the power. The custom wiring design and

15   implementation illustrated in Fig. 1 significantly adds to the cost and size of the system.

16   **[0005]**   Another method of connecting an industrial control system such as a

17   PLC to a load is via a connectorized wire harness or cable. Fig. 2 shows one input module 32

18   and one output module 34 from a PLC 36. The input/output modules 32 and 34 are equipped

19   with connectors 38 and 40 respectively that allow cables 42 and 44 to be used to make

20   connection with various sensors and actuators. Unfortunately, the cable from the input or output

21   module cannot generally connect directly to the sensor or actuator because the connectors 38 and

22   40 on the PLC 36 are rarely configured to accept a sensor signal or provide the actuator power.

23   For this reason, Fig. 3 represents the most common method of connecting a PLC to a sensor or

24   actuator when employing connectors on the PLC. In Fig. 3, cables 40 from the PLC input 32 and

25   output 34 modules connect to circuit boards 46 and 48 which contain terminal blocks 50 for

26   making connections to the control system. Therefore, even when connectorized cables are

27   employed, the prior art still requires making connections through use of individual wire

28   connections such as terminal blocks.

29   **[0006]**   Making a direct connection between a PLC and a sensor or actuator

30   without individual wire connections is problematical. An example situation is when a PLC must

31   be connected to a device that already is equipped with a connector. The need to connect a PLC

32   to such a device is very common. A typical device is a mass flow controller equipped with a

33   connector for connecting signals that must be connected to the PLC. In this case, the connections

34   are complicated by the fact that the PLC output module contains only outputs and the PLC input

35   module contains only inputs, whereas the mass flow controller connector contains signals that

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1 represent both inputs and outputs. To make matters worse, some of the signals are discrete – that

2 is, on/off – and some are continuously varying analog signals. In addition, the mass flow

3 controller also requires application of a power supply voltage and return/ground to the flow

4 controller connector.

5   [0007]   In general, prior art methods and apparatus require the use of custom

6 cable harnesses designed and built to connect the rigid format of a PLC to the varying formats of

7 the disparate devices such as mass flow controllers and power supplies. The difficulty of

8 designing, fabricating and installing complex wire harnesses is so great that the predominant

9 method of connecting PLC's to sensors and actuators is via individual wire connections and

10 terminal blocks.

11   [0008]   Figs. 4a and 4b show two examples of typical non-standard cable

12 construction. In Fig. 4a each of wires 52 and 54 connects to a different pin on connector 56 than

13 on connector 58. The cable of Fig. 4b has two connectors 60 and 62 on one end and a single

14 connector 64 on the other end.

15   SUMMARY

16   [0009]   It is therefore an object of the present invention to provide a method and

17 apparatus wherein customized connections can be made using standard cables.

18   [00010]   It is another object of the present invention to provide a method and

19 apparatus that reduces the cable complexity involved in making interconnections in control

20 systems.

21   [00011]   It is a further object of the present invention to provide a method and

22 apparatus for reducing the number of custom designed cables and individual wire connections in

23 a system.

24   [00012]   It is an object of the present invention to provide a programmable

25 input/output module for directing signals between apparatus through standard cables.

26   [00013]   It is another object of the present invention to provide an improved

27 system for testing cables utilizing programmable input/output modules.

28   [00014]   It is a still further object of the present invention to provide an interlock

29 system for a control system that uses programmable input/output modules and standard cables.

30   [00015]   Briefly, a preferred embodiment of the present invention includes a

31 system for enabling a system controller to receive a selected signal type from, or apply a selected

32 signal type to any selected one or more of a plurality of cable conductors. An input/output

33 module includes a first connector apparatus for making connection with a first transmission

34 line/cable for conveying signals between the module and the system controller. At least one

35 second connector is provided for connecting to a first end of a second standard cable. A second

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1   end of the second standard cable includes a standard cable connector for making connection to a

2   corresponding connector of a device from which data is received or to which a signal is applied.

3   The input/output module is configured to contain programmable logic for enabling the required

4   communication between the controller and the device.

5   [00016]   An advantage of the present invention is that it minimizes or eliminates

6   hand wired interconnections.

7   [00017]   A further advantage of the present invention is that it reduces the cost of

8   hand wiring, including related documentation, wire stripping, wire labeling, installation and

9   testing.

10   [00018]   A still further advantage of the present invention is that it eliminates or

11   minimizes the need for custom cable harnesses.

12   [00019]   Another advantage of the present invention is that it reduces the time

13   required to design a new system.

14   [00020]   An advantage of the present invention is that it reduces the quantity of

15   part numbers in a system.

16   [00021]   A further advantage of the present invention is that it simplifies

17   maintaining systems in the field because a smaller number of cables need to be available to

18   replace damaged or suspected cables.

19   [00022]   A still further advantage of the present invention is that it aids in

20   making system design changes, because new cable designs are generally not required.

21   3.   IN THE DRAWING

22   [00023]   Fig. 1 illustrates a prior art interconnection system using individual

23   wires;

24   [00024]   Fig. 2 illustrates a prior art interconnection system using cables;

25   [00025]   Fig. 3 illustrates the prior art use of circuit boards for interconnecting

26   cable wiring to selected devices;

27   [00026]   Fig. 4a shows a typical prior art custom cable arrangement;

28   [00027]   Fig. 4b shows another typical prior art custom cable arrangement;

29   [00028]   Fig. 5 is a block diagram for illustrating the apparatus and method of

30   the present invention;

31   [00029]   Fig. 6 is a circuit diagram for illustrating further detail of the module of

32   the connectorized configurable system of the present invention;

33   [00030]   Fig. 7 is a block diagram illustrating a system for testing cables using

34   the module of the present invention;

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1   **[00031]**   Fig. 8 is a diagram of a prior art interlock system; and

2   **[00032]**   Fig. 9 is a block diagram of an interlock system using the configurable

3   connectorized input/output module of the present invention.

4   4.   DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

5   **[00033]**   Referring now to Fig. 5 of the drawing, a block diagram is presented for

6   illustration of the method and apparatus of a preferred embodiment of the present invention. The

7   apparatus of the present invention includes a configurable input/output system 65 including an

8   input/output module 66 and one or more cables 68. All of the cables 68 are preferably identical,

9   but the present invention also includes variations in the cables 68. Each cable 68 includes one or

10   more conductors. The I/O module 66 according to the present invention includes a

11   microprocessor that is programmable for enabling a particular transmission of a signal between

12   the module 66 and devices 70, and between the module 66 and a system controller 72. The

13   module 66 also preferably includes one or more standard connectors 74 for connection to the

14   standard cables 68. A connector 76 provides connection to a network (preferably Ethernet) 78

15   for communication between the module 66 and the system controller 72. The module 66 is

16   programmed/configured by input from the system controller 72. Alternatively, the module 66

17   can be configured to be programmed through use of a separate computer (not shown).

18   **[00034]**   For example, the module 66 may be programmed to connect a power

19   supply voltage from either an external device such as a device 79 or from a supply built into the

20   module 66, to any one or more of wires associated with corresponding cables 68 for transmission

21   to corresponding interconnected devices 70. As another example, the controller 72 may program

22   the module 66 to produce or send a signal on any pin of connector 74.

23   **[00035]**   The module 66 may be programmed to enable transfer of

24   communication data between any one of the devices 70 and the controller 72, and this may

25   involve any required analog to digital (A/D) or digital to analog (D/A) conversion by the

26   module 66.

27   **[00036]**   Fig. 6 will now be referred to for illustration of further details of the I/O

28   module 66. The use of the term "standard" as used in the present specification includes any

29   connector and/or cable that is not selected or designed for a particular connection. The term

30   "standard", in other words is used to distinguish the feature of the present invention that enables

31   the user to direct input to any one of the conductors of a cable without the need to design a

32   special connector or cable wire configuration. The term "standard" as used in this sense may or

33   may not include an "off-the-shelf" connector or cable that may be designed for any of various

34   purposes. Nevertheless, it is a preferred embodiment of the present invention for the method and

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1   apparatus to include "standard" connectors and cables in the conventional sense, making wiring

2   less costly, and parts more available.

3   **[00037]**   The I/O module 66 as illustrated in Fig. 6 preferably includes a

4   microprocessor 82 and a power supply 84. Alternatively the power supply can be externally

5   located with interconnection to I/O module 66 as described in reference to Fig. 5. An input

6   line 86 and output line 88 are both shown as required for Ethernet communications between the

7   module 66 and controller 72 according to a preferred embodiment. Other types of

8   interconnections are also included in the present invention according to the type of

9   communications network in use. Line 86 of Fig. 6 represents the connection apparatus required

10   for network communications between a controller such as controller 72 of Fig. 5 and the I/O

11   module 66. Line 88 of Fig. 6 represents the connection apparatus required for communication to

12   another I/O module, such as 124 in Fig. 7 between I/O Modules 120 and 122. In general, the

13   microprocessor 82 is configured/programmed by a controller 72 to receive instruction from the

14   controller as required to sense a particular selected device 96, which may be for example a

15   pressure sensor, temperature sensor, etc., and provide the corresponding data to the system

16   controller. The microprocessor 82 is also programmed/directed by the controller to cause a

17   particular signal to be applied to any selected one or more of conductors of one or more cables

18   such as cable 94. In addition, the microprocessor is programmed to respond to direction to send

19   a selected signal type from a device 96 to the system controller.

20   **[00038]**   Although Fig. 6 shows only one line 94 for simplicity of illustration, the

21   present invention includes any number of lines 94, connectors 114 and devices 96. The

22   module 66 provides a selection of interconnection devices 98-112 for each of any of a plurality of

23   lines 94. Each set of devices 98-112 is dedicated for making a connection to one line 94. The

24   present invention therefore includes a set of interconnection apparatus such as 98-112 and

25   corresponding required programmed logic in the microprocessor 82 for each line 94 leading to

26   each one of the connector pins of connectors 114, the pins for example as indicated by the circles

27   on connector 114, for making connection to any corresponding device such as device 96.

28   **[00039]**   As an example of operation of the system 65, the microprocessor may

29   be programmed to recognize particular input data, included for example in an Ethernet packet on

30   line 86 containing instruction to transmit the data as an analog signal on line 94 to device 96.

31   The programming in this case would instruct the microprocessor to direct/convert the data

32   through apparatus 98 having a digital to analog converter 116. Facility for making this

33   connection is symbolized by relay "R1" which would be activated to make the required

34   connection from the device 116 to the device 96. As another example, if line 94 were to carry 15

35   volts to the device 96, the microprocessor would be programmed to respond to a signal from the

1 controller to activate relay R6. In this manner, the system 65 allows communication of a selected

2 variety through any line such as 94, and application of any one of a variety of signals to be sent

3 to any selected line such as 94 and thence to a corresponding device 96. The cable connecting to

4 the lines such as line 94 can therefor be any cable capable of transmission of the required signals,

5 which as explained above is preferably a conventionally standard cable.

6   **[00040]** The circuit switching apparatus (R1-R8) are shown diagrammatically as

7 electromechanical relays. In the preferred embodiment, this switching apparatus is realized in a

8 semiconductor circuit. A semiconductor circuit can be realized far less expensively and can act

9 faster than an electromechanical relay circuit. An electromechanical relay is used in order to

10 show the essence of the invention.

11   **[00041]** As shown in Fig. 6, any one of the eight signal paths indicated as

12 98-112 can be interconnected to line 94. Fig. 6 shows, for example, four different power supply

13 signals including 24V DC, ground, 15V DC and –15V DC. The present invention also includes

14 any quantity or value of signals. As described above, the module 66 is configured with a set of

15 inputs such as 98-112 for each line 94 (Fig. 6) in each cable 68 (Fig. 5).

16   **[00042]** The lines and interconnections can carry any signal type. For example,

17 signals can contain frequency information such as that found in feedback from servo motors. Or

18 these signals can represent serial communication carriers handling, for example, RS-232 data or

19 fieldbus data such as Device Net, Profibus or Ethernet.

20   **[00043]** Fig. 6 also illustrates the facility for connection of four non-power

21 signals by paths 98-104. Paths 98 and 100 include A/D and D/A converters, as well as switching

22 apparatus (R1 and R2), for situations where such conversion is necessary to accommodate

23 different transmission and reception capabilities/requirements of the controller 72 and a

24 device 70 (such as device 96). Paths 102 and 104 provide for passage of digital signals in either

25 direction. In further explanation, the controller can direct the module 66 to send a digital signal,

26 which when received by the module 66, can be sent to a buffer 118, from which the

27 microprocessor 82 in response to direction from the controller can send the signal to any one of

28 the contacts on connector 114 by activating the required relay in a path such as path 104 to

29 connector 114, to send the required signal to the desired contact of the desired connector. Again,

30 the routing of the signals is symbolically illustrated as accomplished by closing the associated

31 relay (R1-R8). In the case of the aforementioned digital output signal, as shown in Fig 6,

32 relay R4 would be closed, but relays R1-R3 and R5-R8 would be opened, thus routing the

33 requested digital output to line 94 and the corresponding pin of the standard I/O connector 114.

34 Similarly, the module 66 can receive a digital signal from a device 72, such as device 96, and in

35 response to direction from the controller can send a copy to the controller 72. In this case,

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1   relay R3 would be closed, while relays R1-R2 and R4-R8 would be opened, thus routing the

2   digital signal from the given pin of the standard I/O connector 114 through path 102. Paths 98

3   and 100 accommodate analog to digital conversion as required. Finally, the configurable I/O

4   system 65 can be isolated from a signal such that the signal appears to be *disconnected*. This

5   disconnection is achieved by opening all relays, R1-R8.

6   [00044]   Referring again to Fig. 5, a preferred method of the present invention

7   includes the use of the system 65 in a control system wherein a controller 72 receives data from

8   or sends data to one or more devices 70 through an I/O module 66 that is programmed to receive

9   signals from and place signals on any selected conductor of a selected cable to a device 70. In a

10   preferred embodiment, the device 72 is a system controller in communication with the I/O

11   module 66 through an Ethernet system 78. Alternatively, the device 72 can be of other

12   configuration, such as a general purpose computer, and the communications line 78 can be of any

13   type, such as a standard computer cable, etc.

14   [00045]   A further method of the present invention includes the use of the

15   module 66 for testing cables. Fig. 7 shows a first I/O module 120, connected to a second I/O

16   module 122 with a cable 124 to be tested. According to a preferred embodiment, a system

17   controller 126 is programmed to direct module 120 to place a particular signal on a selected one

18   of wires 128 in cable 124. The signal can be for example, a DC supply voltage or other signal

19   type as required for testing the cable 124. The controller directs the second module 122 to scan

20   the pins 130 of the second module 122. The results of the scanning are sent to the controller 126,

21   whereby the controller can know if the correct signal is on the correct pin to determine the

22   condition of the cable. In addition to determining the quality of transmission through a single

23   selected cable conductor, the controller can scan and detect a signal on any pin 130 of the

24   connector of module 122, and therefore can determine if any of the conductors 128 are shorted to

25   each other, and can determine the level of cross talk between the conductors 128. Fig. 7 shows

26   dashed lines 132 and 134 representing communication lines between the system controller 126

27   and the Modules 120 and 122.

28   [00046]   A still further embodiment of the present invention includes a method

29   wherein a module configured to include the features of module 66 is combined with an interlock

30   for providing a safety feature in a system. Fig. 8 illustrates a prior art interlock system for

31   protecting use of a gas valve 134. Three relays 136, 138 and 140 must conduct current from a

32   24VDC supply 142 in order for the gas valve 134 to receive operating power. The electrical

33   windings for operating the relays 136, 138 and 140 are symbolized by the circles 142, 144 and

34   146. The power to each winding is controlled by the sensor units 148, 150 and 152. If any one

35   of the three sensor units is activated and therefore disconnects power to the corresponding

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1   winding, the associated relay disconnects/open circuits and shuts off power to the gas valve. The

2   interlock circuit of Fig. 8 is often built into a custom circuit board requiring custom wiring.

3   [00047]   An embodiment of a method of the present invention is illustrated in

4   Fig. 9 wherein configurable connectorized I/O Modules 166, 168 and 170, such as module 66,

5   are used to minimize or eliminate custom wiring in an interlock system. The Modules 166, 168

6   and 170 may be similar or identical to the module 66 of Figs. 5 and 6 with connections to the

7   interlock Modules 180, 182 and 184. The interconnections indicated in Fig. 9 can all or in part

8   be accommodated with standard connectors and cabling, with the specific direction/routing of

9   signals accomplished by programming the configurable, connectorized I/O modules.

10   [00048]   The exemplified system 154 of Fig. 9 includes a system controller 156

11   for controlling an operation including a device 158 such as a mass flow control, etc. The system

12   154 includes an interlock system that allows operation of the device 158 only if the state of all

13   three safety sensors 160, 162 and 164 indicate that operation conditions are appropriate. The

14   sensors can be of any type for the purpose. The three examples are a proximity switch 160, a

15   safety interlock 162 and a limit switch 164.

16   [00049]   The system controller 156 is connected to each of the three

17   configurable, connectorized I/O Modules 166, 168 and 170 which provide the programmable

18   flexibility as described above, to allow standard cables and connectors to be used throughout the

19   system to make the various connections indicated. I/O Modules 166, 168 and 170 are shown

20   overlapping the interlock Modules 180, 182 and 184 indicating that the interlock Modules 180,

21   182 and 184 plug into the I/O Modules 166, 168 and 170. In the preferred embodiment, the

22   interlock Modules 180, 182 and 184 plug into connector 74 of an I/O module such as

23   Module 600 of Fig. 5 in place of a cable 68. The interlock Modules 180, 182 and 184 each

24   contain a device connector 74 into which a cable 69 plugs for interconnecting the devices 158-

25   164. The interlock Modules 180, 182 and 184 therefore reside between the I/O Modules 166,

26   168 and 170 and the devices 158-164 to which they attach, including as shown by example in

27   Fig. 9 a proximity switch 160, limit switch 164, , and safety interlock 162, and device 158.

28   [00050]   The system controller 156 communicates with I/O Modules 166, 168

29   and 170, and with the interlock processor 172 by way of a network, such as Ethernet as indicated

30   by lines 174. Apparatus for accomplishing Ethernet communication will be understood to those

31   skilled in the art, and this need not be illustrated in order to reproduce the invention. A power

32   supply 176 is shown with the connections symbolized by lines 178. An interlock module (180,

33   182, 184) is attached to each of the I/O modules (166, 168, 170). Each interlock module (180-

34   184) is attached to the interlock processor 172 through cables/buses as indicated by lines 186,

35   188 and 190.

1   [00051] The interlock system of Fig. 9 will not be explained in further detail. In

2   general, the system 154 includes interlock modules (180, 182, 184) connected to an interlock

3   processor 172 via bus lines (186, 188, 190). The *Interlock Modules* have two functions: (1) The

4   first function, of the Interlock Modules 180 and 182, is to transmit the state of certain inputs, for

5   example 192, 194 and 195 from sensors 160, 162 and 164, such inputs being a subset of all

6   inputs and being called *Interlock Inputs*, to the Interlock Processor 172 via the Interlock Buses

7   186 and 188. Any input (192, 194, 195) connected to any interlock module (180-184) can be

8   wired within the interlock module such that the input drives a relay coil, as shown in Figure 8,

9   with relay coils labeled (142, 144, 146). When these relay coils are actuated, the associated relay

10   contacts close. These relay coils each activate a contact resulting in a signal being sensed by or

11   sent to the Interlock processor 172 via the interlock buses 186 and 188 to the Interlock

12   Processor 172. The function of the Interlock Processor will be described shortly. (2) The second

13   function, of the Interlock Module 184, is to receive one or more interlock signals from the

14   Interlock Processor 172 via the Interlock bus 190. The Interlock Processor is wired such that the

15   interlock signal or signals that the processor sends on the bus 190 drives a coil of a relay located

16   in the Interlock module 184 whose contacts are in series with an output of the I/O module 170.

17   This output 197 is therefore *interlocked*. That is, the I/O module 170 can attempt to turn on an

18   output connected to the device 158, but that output 197 will be prevented from progressing

19   outside the Interlock Module 184 (that is, interlocked) unless the Interlock Processor 172 drives a

20   signal on the Interlock bus 190 which closes a relay in series with the output 197. The Interlock

21   Processor 172 is responsive to inputs from the Interlock Modules 180 and 182 by performing

22   Boolean logic upon the inputs to generate one or more interlock outputs on bus 190 that are

23   routed to the Interlock Module 184 and thereby interlock output 197 from the I/O Module 170.

24   The Interlock Processor 172 preferably does all of its processing using relays. Relays are

25   common in safety circuits since they are simple and reliable. Silicon switches and

26   microprocessors have the reputation for being less reliable and prone to various hardware or

27   software glitches. Nonetheless, nothing in this application precludes the use of silicon

28   processors, switches or logic. The cables 186, 188 and 190 are shown making direct connection

29   between each interlock module and the interlock processor.

30   [00052] In operation, the proximity switch 160 provides an interlock input 192

31   that is connected directly to the first interlock module 180. The safety interlock 162 provides a

32   similar input 194. These two interlock inputs 192 and 194 are sensed by the system

33   controller 156 by way of connection between the interlock module 180 and the I/O module 166,

34   and input monitoring communications between the I/O module 166 and system controller 156 by

35   way of network 174. The interlock module 180 contains one relay for each interlock input 192

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1 and 194. These relays (not shown) are for driving a signal via the Interlock Bus 186 to the

2 Interlock Processor 172. The Interlock Processor 172 contains one relay for each interlock

3 input 192 and 194. The relays are arranged within the Interlock Processor 172 to perform a

4 Boolean operation on the Interlocks 160, 162, 164 and generate an interlock output that is routed

5 via the Interlock Bus 190 to the Interlock Module 184. Inside the Interlock Module 184 is one

6 relay (not shown) for each output such as output 197 to be interlocked. In other words, although

7 only one output 197 to one device 158 is shown in Fig. 9, the concept of the present invention

8 applies to any number of inputs, outputs and devices. When the Interlock Processor 172

9 determines that the Interlock inputs 160, 162, 164 are in their correct states for proper system

10 operation, the Interlock Processor 172 drives a signal via the Interlock bus 190 and causes the

11 relay in the Interlock Module 184 to close, thus allowing an output on line 197 and therefore the

12 device 158 to be enabled or turned on.

13   **[00053]** While a particular embodiment of the present invention has been shown

14 and described, it will be obvious to those skilled in the art that changes and modifications may be

15 made without departing from the spirit of the present invention, and therefore the appended

16 claims are to include these changes and alterations as follow within the true spirit and scope of

17 the present invention.

18   **[00054]** What is claimed is: